Standardisierung optischer Kommunikation im Weltraum durch CCSDS

(Consultative Committee for Space Data Systems)

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GOSATCOM 2019, Neubiberg, 20190911

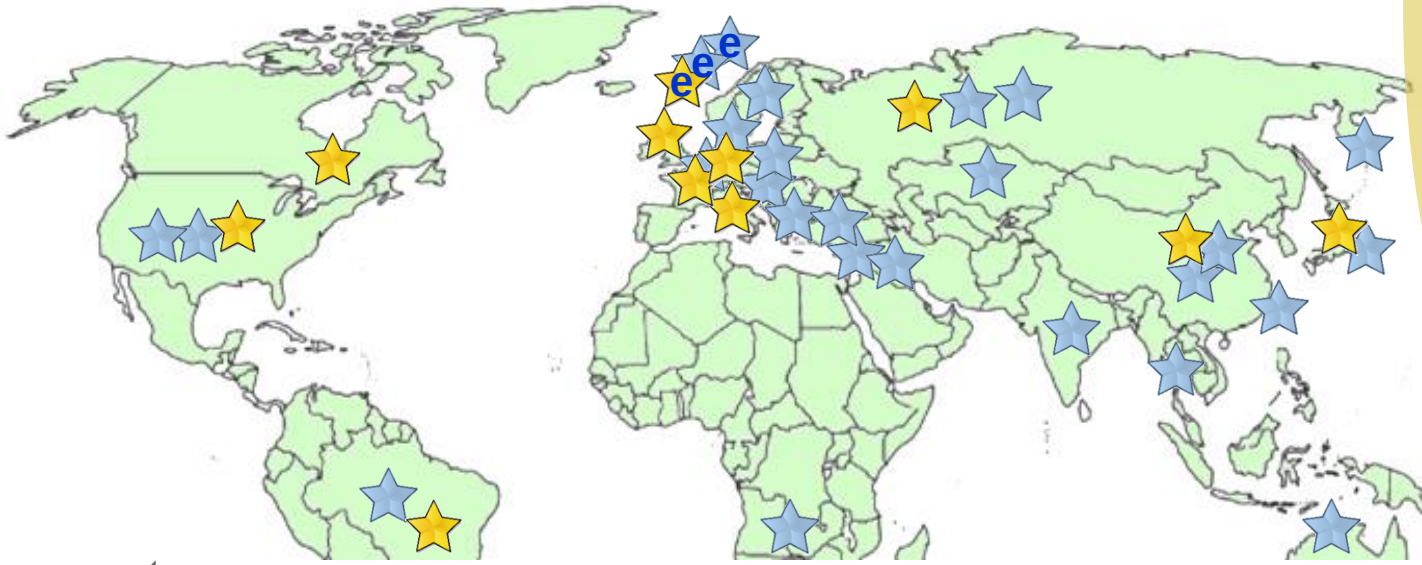
DLR

CCSDS - *Consultative Committee for Space Data Systems*

- Founded in 1982 by the major space agencies of the world, the CCSDS is a multi-national forum for the development of communications and data systems standards for spaceflight.
- The goal is to **enhance governmental and commercial interoperability** and cross-support, while also **reducing risk, development time and project costs**.
- 135 standard books published
- More than 900 space missions have chosen to fly with CCSDS-developed standards
- Drivers were deep space missions interop.: Pioneer 1968/72/73 (Conv.Codes), Voyager Missions 1977 (ReedSolomon) + ext. VIM, Rosetta 2004 (Turbo Codes)
- Cooperation with “Interagency Operations Advisory Group” (IOAG, identifies needs for standardization) , and agreement with ISO

CCSDS Overview - Participation

- CCSDS – An Agency-Led International Committee
  - Currently 11 **Member** agencies
  - Currently 29 **Observer** Agencies
  - Agencies represent 27 nations (and 3 European orgs)
  - Currently 118 **Commercial Associates**
  - ~160-180 attendees at Spring/Fall meetings
- Also functions as an ISO Subcommittee
  - TC20/SC13 - Space Data & Info Transfer Systems



MEMBER AGENCIES

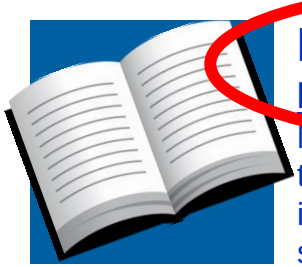
ASI/Italy
CNES/France
CNSA/China
CSA/Canada
DLR/Germany
ESA/Europe
FSA/Russia
INPE/Brazil
JAXA/Japan
NASA/USA
UKSA/UK

OBSERVER AGENCIES

ASA/Austria
BFSPO/Belgium
CAS/China
CAST/China
CLTC/China
CSIRO/Australia
DCTA/Brazil
DNSC/Denmark
EUMETSAT/Europe
EUTELSAT/Europe
GISTDA/Thailand
HNSC/Greece
IKI/Russia
ISRO/India
KARI/Korea
KFKI/Hungary
MOC/Israel
NCST/USA
NICT/Japan
NOAA/USA
NSARK/Kazakhstan
NSPO/Taiwan
SANSA/South Africa
SSC/Sweden
SSO/Switzerland
SUPARCO/Pakistan
TsNIIMash/Russia
TUBITAK/Turkey
USGS/USA

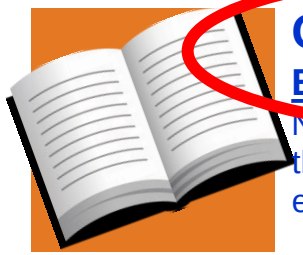
source: CCSDS

CCSDS Books Colours



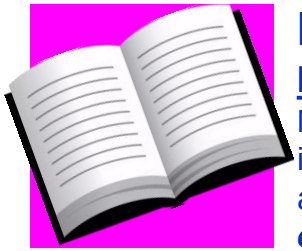
BLUE BOOKS
Recommended Standards

Normative and sufficiently detailed (and pre-tested) so they can be used to directly and independently implement interoperable systems (given that options are specified).



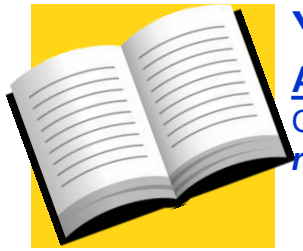
ORANGE BOOKS
Experimental

Normative, but may be very new technology that *does* ***not yet have consensus*** of enough agencies to standardize.



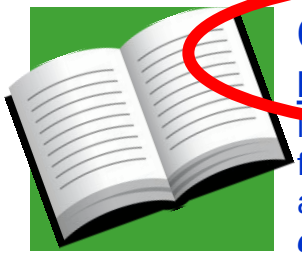
MAGENTA BOOKS
Recommended Practices

Normative, but at a level that is not directly implementable for interoperability. These are Reference Architectures, APIs, ***operational practices***, etc.



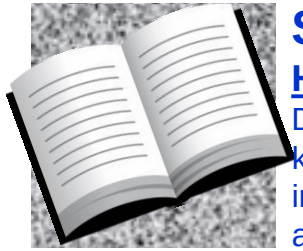
YELLOW BOOKS
Administrative

CCSDS Procedures, Proceedings, ***Test reports (prototypes)***, etc.



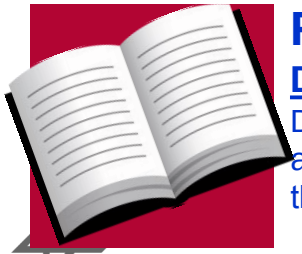
GREEN BOOKS
Informative Documents

Not normative. These may be foundational for Blue/Magenta books, describing their applicability, overall archtecture, ***ops concept***, etc.



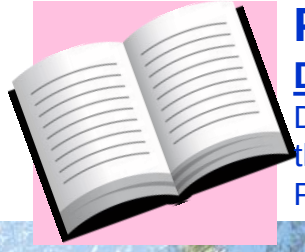
SILVER BOOKS
Historical

Deprecated and retired documents that are kept available to support existing or legacy implementations. Implication is that other agencies may not cross-support.



RED BOOKS
Draft Standards/Practices

Drafts of future Blue/Magenta books that are in agency review. Use caution with these… they can change before release.



PINK BOOKS/SHEETS
Draft Revisions For Review

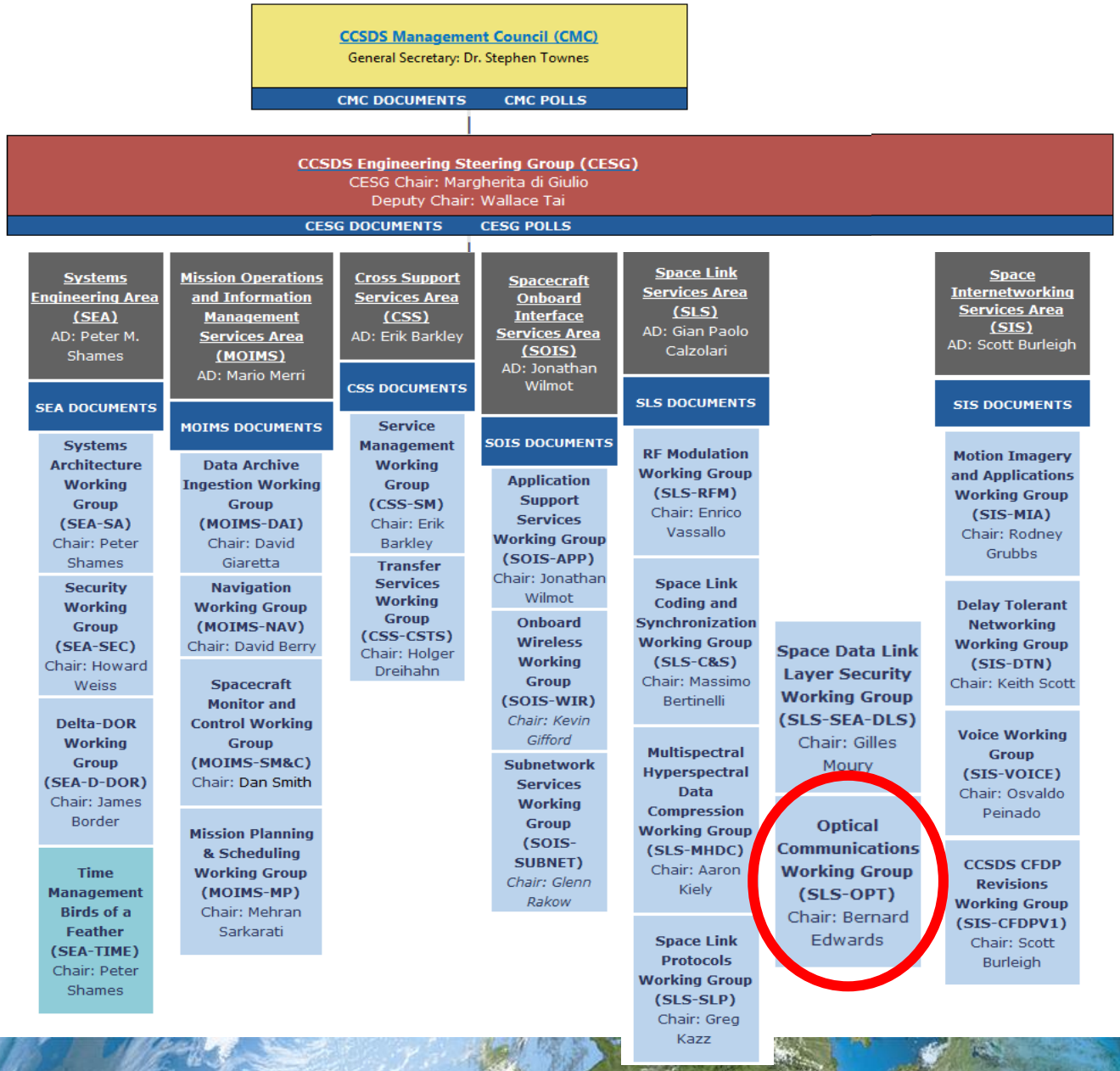
Draft Revisions to Blue or Magenta books that are circulated for agency review. Pink Books are reissues of the full book,

DLR

source: CCSDS

CCSDS Technical Working Groups

- monatliche TeleCons der AGs
- halbjährliche Treffen (US / EUR)



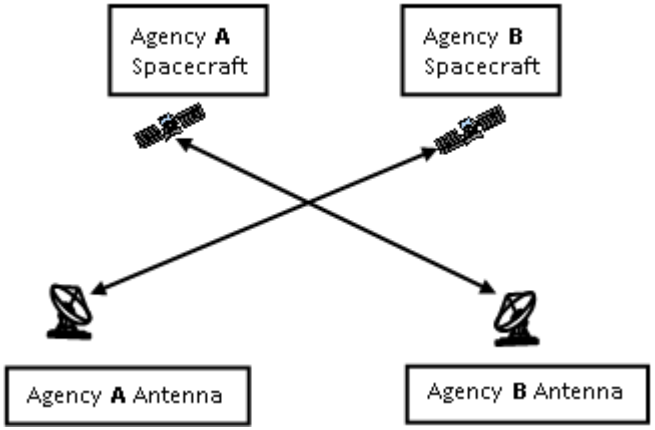
Motivation for LaserComms: Data Rate, Spectrum availability, Size & Mass & Power

Optical Communications International Standardization

- ***Sharing*** optical communication ***ground stations*** or ***relay satellites*** among the international space agencies would allow the agencies to ***share the cost*** of the communications infrastructure.

- … and ***increase system performance***,
  e.g. sharing OGSs between agencies to recover orbit-constraints or during cloud-blockage.

- What is standardized:
  - Downlink Wavelength, data-rates, modulation formats, Uplink-Beacons
  - Further: Coding-Algorithms, Frame-formats, Synchronization and Interleaving…



Traditional International RF Cross Support

OGS: Optical Ground Station

CCSDS-Standardization in group “SLS-OPT”: 3 Regimes

1. **High Photon Efficiency HPE** (Low Photon Flux):
   led by NASA, for ***future Deep Space Missions: highest sensitivity, up to ~1Gbps***
   → blue books

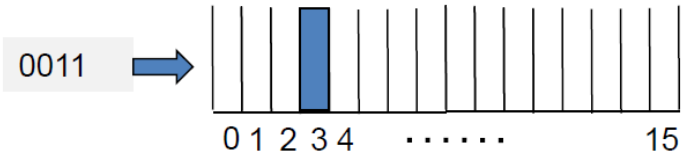
2. **High Data Rate HDR** (High Photon Flux):
   Multi-Gbps, multi-scenarios, near-Earth (up to moon distance)
   Two proposals: ESA/DLR (EDRS) and NASA (LCRD)
   → orange books

3. **On-Off-Keying O3K** (LEO-Downlinks, ~~and ISLs~~):
   led by DLR, partners: JAXA (/NICT), ESA, CNES, NASA
   IM/DD space-GND links, 10Gbps to 1Mbps, 1550nm
   employing experience from:
   OICETS/SOTA (JAXA/NICT), OPTELμ (ESA), OPALS (NASA), OSIRIS (DLR)
   → blue books

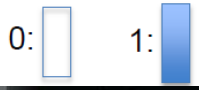
standardization work started in 2014

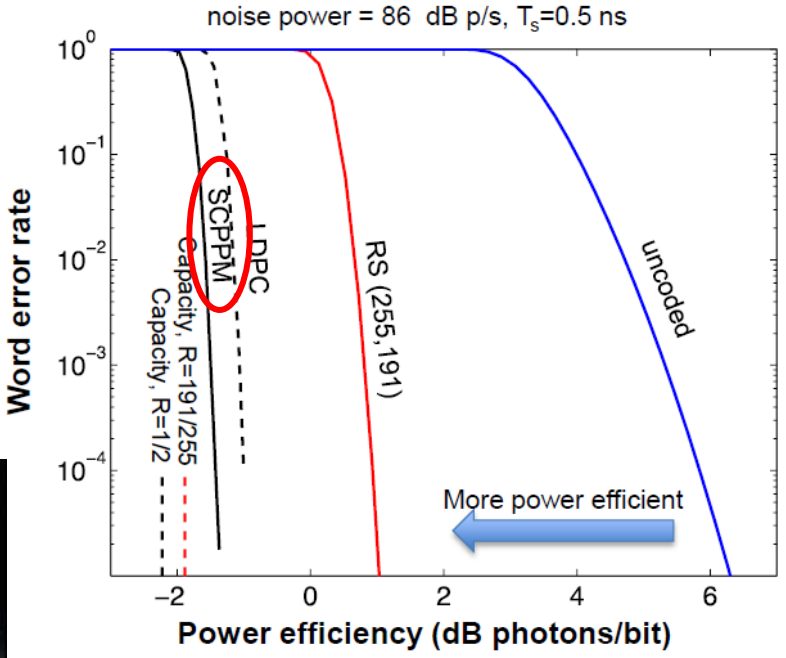
1. Deep Space – Low Photon Flux → (near) Single Photon Counting

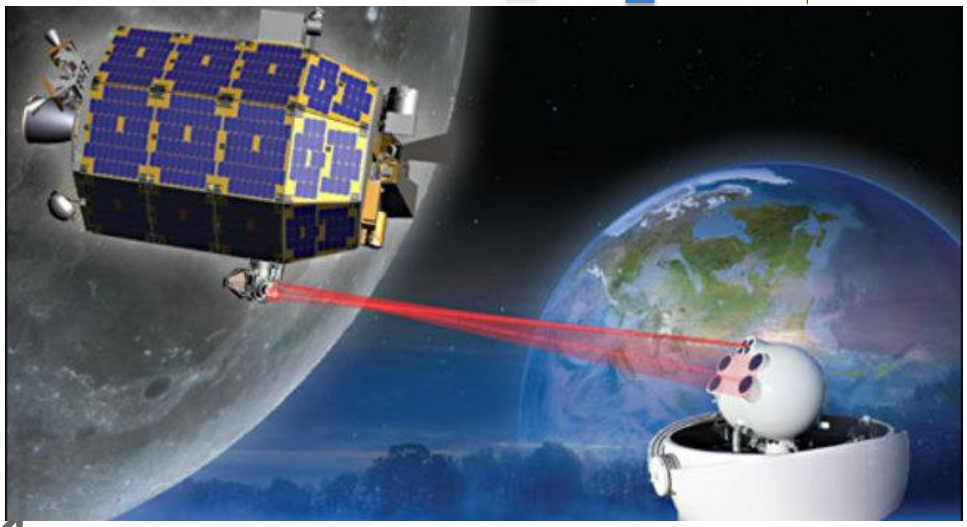
Pulse-Position-Modulation (PPM): $\log_2 M$ bits are represented by a single pulse out of M slots (here M=16)



On-Off-Keying (OOK):







Lunar Laser Comms Demonstration LLCD (2013)
→ reference mission

material: NASA

2a. HDR Proposal: ESA/DLR – operational EDRS-relais

LCT- Application EDRS/ GMES (ESA/EU Program)

EDRS
Launch EDRS-A
Launch EDRS-C

Technical Data – GEO LCT

- ✓ 1064 nm wavelength
- ✓ user data rate 1.8 Gbps (bi-directional)
- ✓ Distance: 45.000 km
- ✓ Telescope Diameter: 135mm
- ✓ weight: 53 kg
- ✓ Dimensions: 60x60x74 cm
- ✓ power consumption: 180 W max.

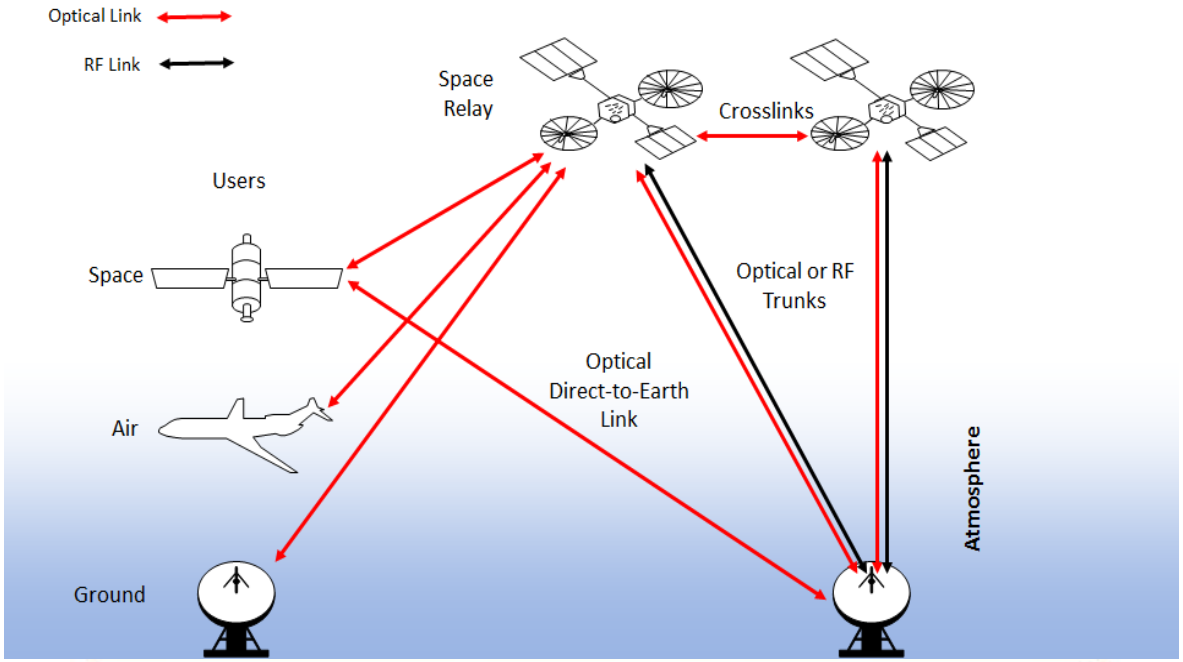
Sentinel 1 B
Launch: 2015

Sentinel 2 B
Launch: 2015

Photos: ESA

2b. HDR Proposal: NASA, CNES, JAXA, based on future LCRD and JDRS (both GEO relais)

- DVB-S2 codes (others under consideration)
- n-PSK (BPSK and QAM under consideration
- 15xxnm (DWDM C-Band)



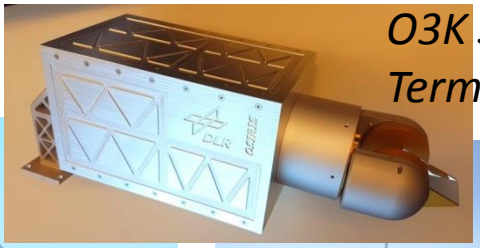
Primary near term interest is in relay architecture for conveying data from user to terrestrial ground network

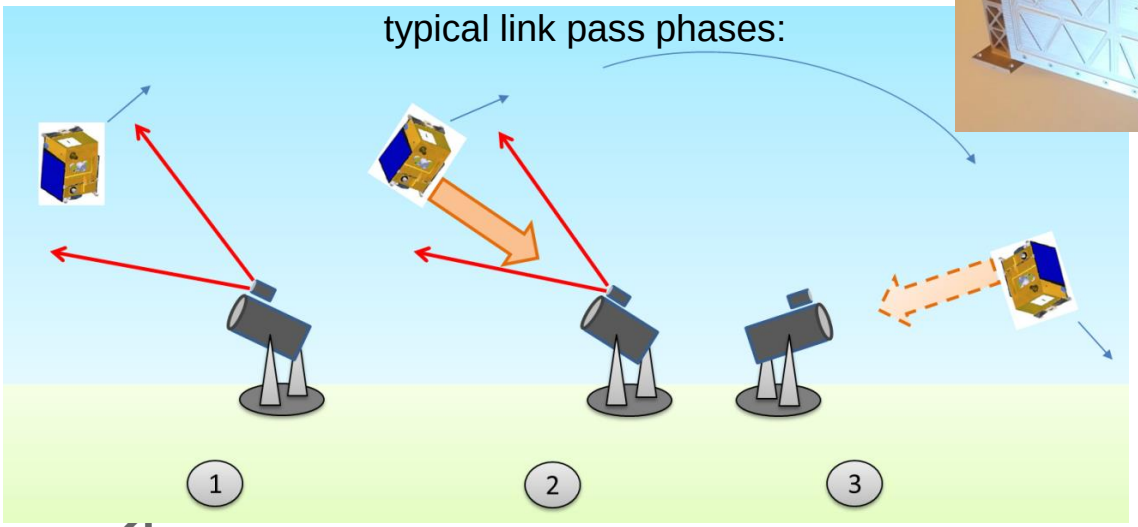
material: NASA

3. Optical On-Off-Keying (O3K)

LEO Direct to Earth Data Downlinks at up to Multi-Gbps,
flexible Link Budget to compensate the ***highly dynamic parameters*** (distance/el., atmos atten./el., signal power per mission, OGS-aperture, SC-terminal abilities…)

Low Complexity → Robust and low cost; employing terrestrial fiber comms techn.
Varying link budget → support a wide variety of data rates and code rates
Asymmetric link geometry → small Space-Tx-Terminal, medium-sized GND-OGS





OGS

Status Optical Space Links Standardisierung in CCSDS

- Zwei BlueBooks zu High Power Efficiency (HPE) – [Deep Space Comms]: nahe release (PHY and Sync&Cod): Einigkeit innerhalb der Working Group
- Optical On-Off-Keying (O3K) – [Earth-Orbit Downlinks]:
  PHY-draft ist fertig, Sync&Coding Inhalt wird erarbeitet, wird als Kapitel in der nächsten Revision zu den BlueBooks ergänzt
- MagentaBook (Recommendet Practice) zu „Atmospheric Characterization for Optical Communication Systems“ kann bald veröffentlicht werden
- Zwei separate Orange Books on High DataRate (HDR) – *[Near Earth]* werden erarbeitet (kein Konsensus erforderlich)
- GreenBooks (informative) zu HPE und O3K werden erarbeitet

Herausforderungen und Vorteile der CCSDS-Mitarbeit

- Zeitaufwendig und kostspielig (USA-Reisen, 2x Prototypenbau):
ideal 41 Monate bis BB, in Praxis viel länger

- Personen oder Agenturen sind später nicht sichtbar → Sichtbarkeit für Personen oder Institute existiert nur über separate Veröffentlichungen

- Einstimmigkeit innerhalb der Gruppe für BBs erschwert Konsensfindung: gegenseitiges Überzeugen durch teils aufwendige Untersuchungen

- politische Motivationen erschweren manchmal optimale technische Entscheidungen …

+ … andererseits gibt es *OrangeBooks* als kurzfristigen Ausweg

+ Nutzung der existierenden gut funktionierenden Organisation “CCSDS” für die Erarbeitung von Standarddokumenten

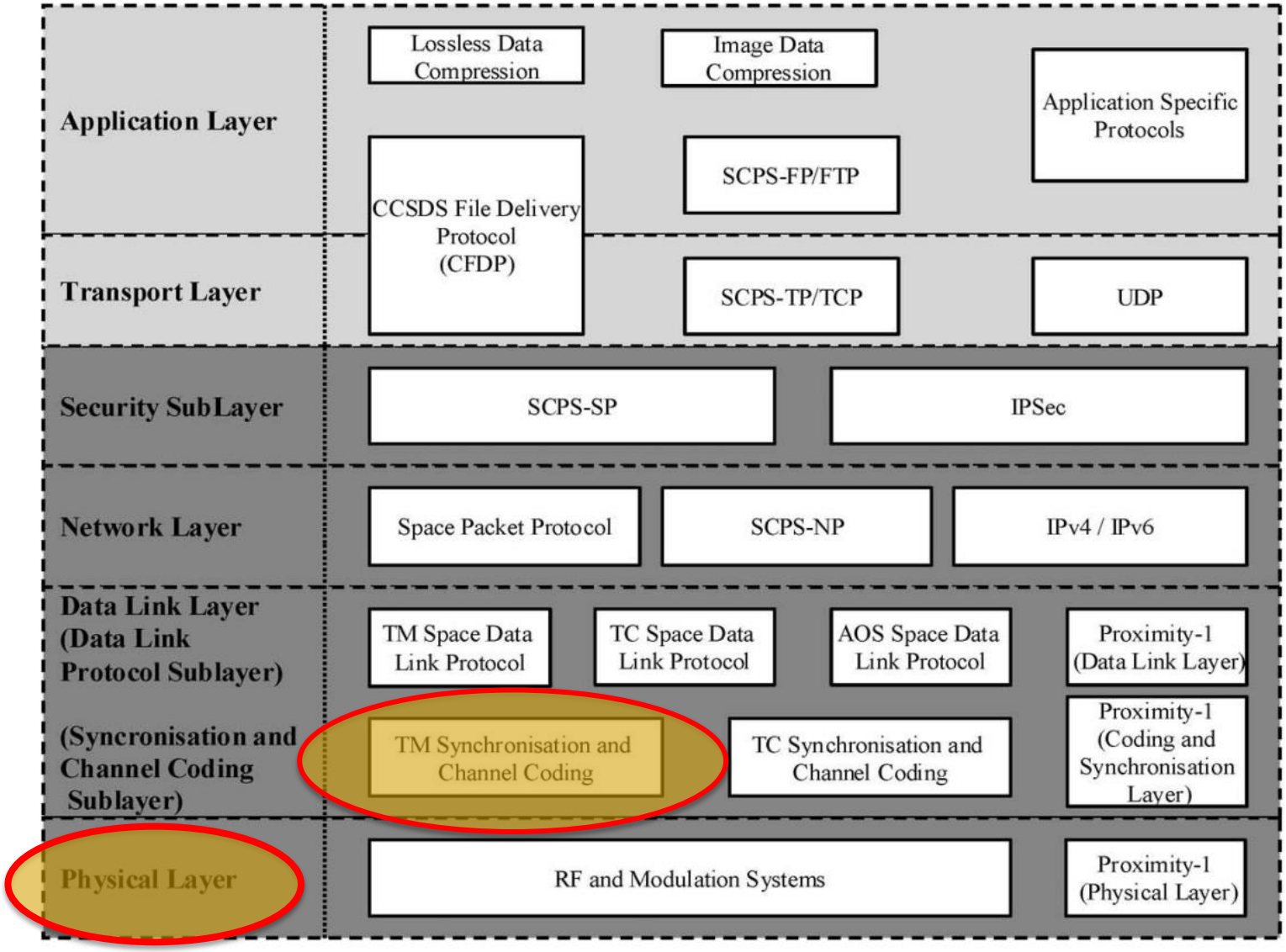
+ Übernahme durch andere Standardisierungs-Organisationen (ISO)

+ wichtige Diskussionen mit den besten Experten zum Thema

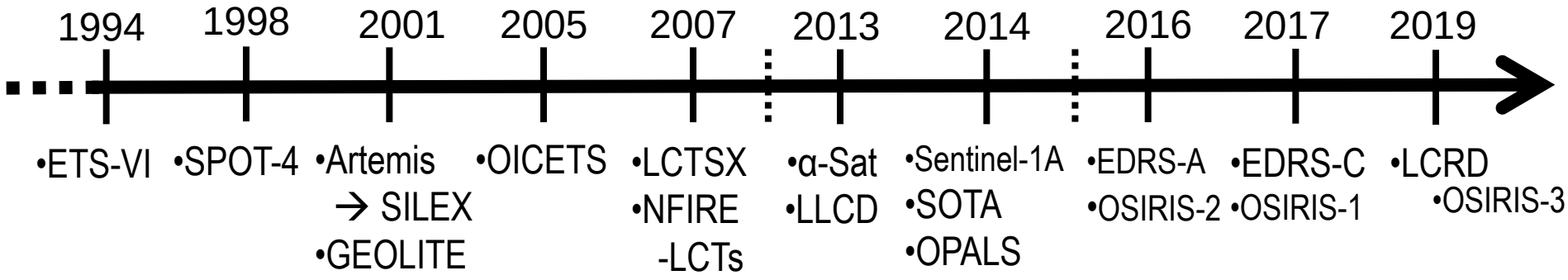
Siehe: www.CCSDS.org cwe.ccsds.org www.ioag.org

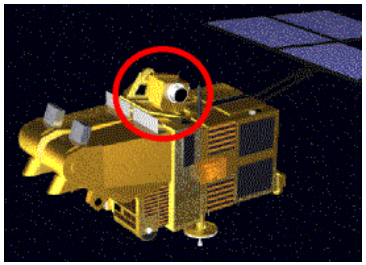
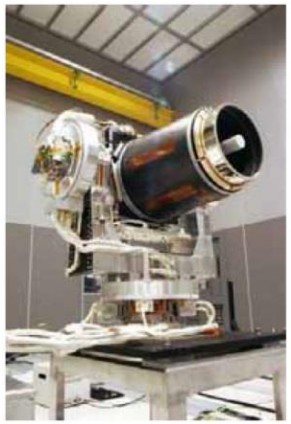
BACKUP

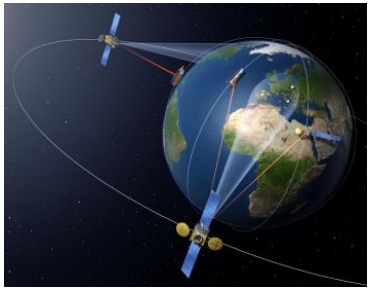
CCSDS Protocol Stack

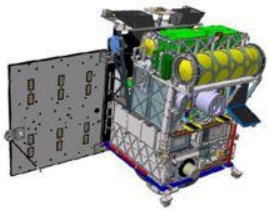


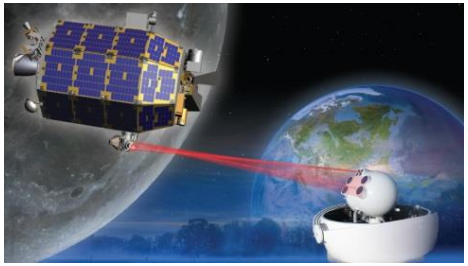
Development of Laser-Comm. Space-Missions (selection)

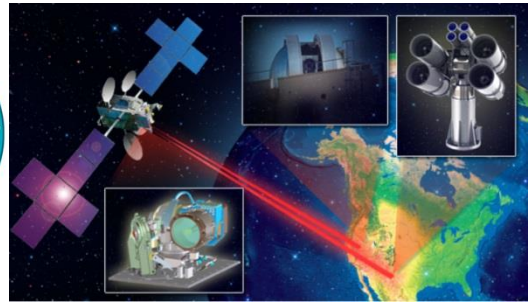






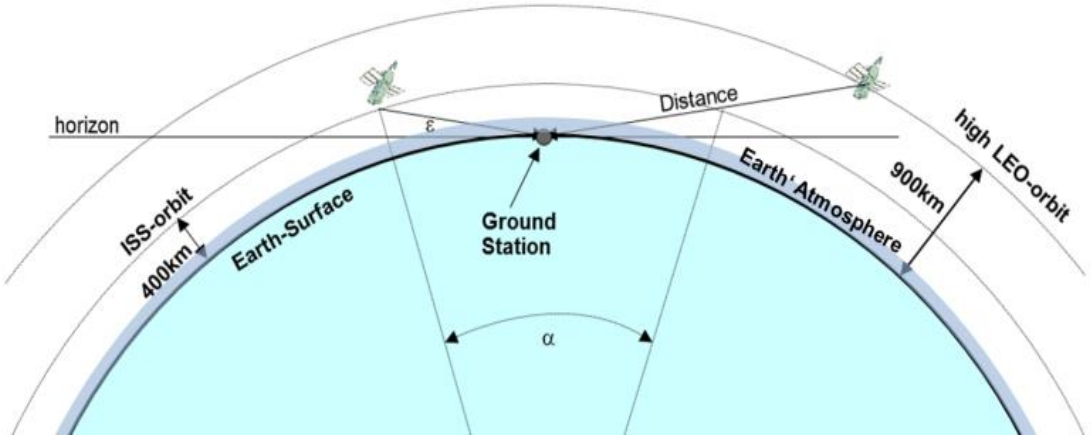


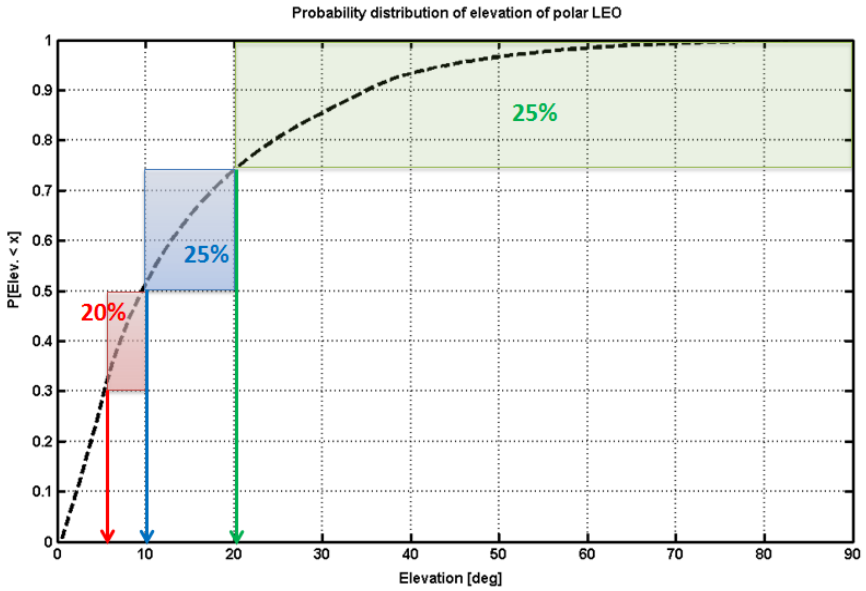
Japan, ESA, Germany, USA, France

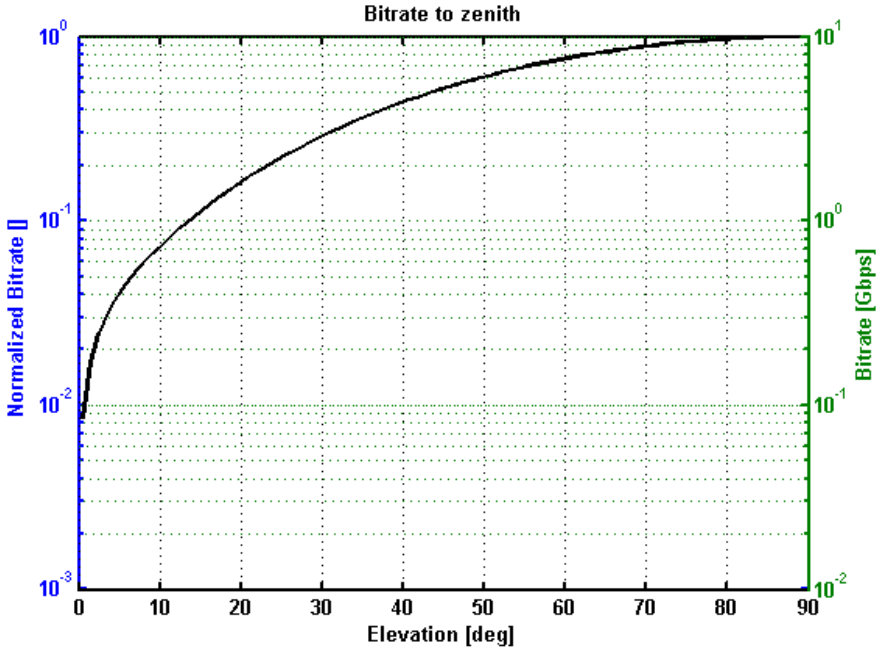
else: P.R.China, Russia

O3K Scenario: Impact of Orbit-Geometry and Atmos. Atten.



Geometry for 400km and 900km orbit





LEO Visibility vs. Elevation → *< 20° !*